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IDENTIFICATION OF *MYOTIS CALIFORNICUS* AND *M. LEIBII* IN SOUTHWESTERN NORTH AMERICA

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Within temperate North America there are, perhaps, no two bats more similar than *Myotis californicus* (Audubon and Bachman) and *Myotis leibii* (Audubon and Bachman). Over much of their respective ranges they are allopatric, and specimens may be identified on strictly geographic grounds. However in the southwestern United States and Mexico where their ranges overlap broadly and where *californicus* is known to be highly variable, problems of identification arise. Most students of southwestern bats agree that the two kinds are closely related but nonetheless distinct. For example, Findley (1972) includes the two species in the "Leibii group" of the subgenus *Selysius* within *Myotis*.

Most problems with the allocation of specimens appear to center in the southwestern portion of New Mexico and adjacent Arizona, Texas and Mexico (Barbour and Davis, 1969; Anderson, 1972; Findley et al., in manuscript), probably due to the increased variability of *californicus* in this area (Bogan, 1973). The collection of good series of both kinds of bats from Hidalgo County, New Mexico, by J. D. Druecker and others from the University of New Mexico offered the chance to ascertain the status of the two bats in this area and, hopefully, to establish reliable quantitative procedures for identifying these bats, both in the field and in the museum.

Methods and Materials

Thirty-four *M. leibii* and 50 *M. californicus*, all adults, from various localities in Hidalgo County, New Mexico, were examined. Sexes were

TABLE 1. Traditional characters used to separate *Myotis californicus* and *M. leibii.*

Character	*californicus*	*leibii*
Facial coloration	Brown	Black
Ear color	Brown	Black
Dorsal pelage	Dull-tipped, not burnished or glossy	Shiny-tipped, glossy or burnished
Third metacarpal	As long as forearm (over 30.5 mm)	Shorter than forearm (less than 30.3 mm)
Braincase	Rounded	Flattened
Forehead profile	Rises abruptly	Rises gradually
Skull size	Smaller	Larger

combined for this analysis, as I have found that sexual dimorphism is not marked in these two species. The fourteen characters utilized, measured as described in Bogan (1973), are: total length, tail length, hindfoot length, ear length, forearm length, tibia length, condyle-premaxillary length, condylocanine length, maxillary toothrow length, cranial breadth, cranial depth, least interorbital breadth, rostral breadth, rostral length.

The specimens were initially identified using only published characters (Table 1). The crania were examined closely to determine additional characters for identification. Bats were grouped into samples for statistical analysis in two ways: first, using just two samples, Hidalgo County *californicus* and Hidalgo County *leibii*; and second, by subdividing the two species into samples from eastern, central and western Hidalgo County. These samples correspond to the three major mountain ranges in Hidalgo County and likewise to most of the productive collecting localities in the county (Findley and Traut, 1970).

Frequency distributions for each variable were prepared to examine normality of distributions and degree of overlap between *californicus* and *leibii.* Means and variances were then calculated for the two species. Additionally, bivariate scattergrams were prepared for most pairs of variables.

The data matrix was subjected to a two-group discriminant analysis (BMD04M) which gives a discriminant function as well as the discriminant coefficients for each variable enabling the identification of new specimens. Next, a stepwise discriminant analysis (BMD07M) yielding five canonical variates and a classification matrix based on the posterior probabilities and generalized distance values was performed, allowing an estimate of the degree of phenetic overlap. Additionally, the data were subjected to a principal component analysis (BMD01M) and to a numerical taxonomic analysis (NTSYS, developed by F. James

TABLE 2. Basic statistics for 14 variables of *Myotis californicus* and *M. leibii* from Hidalgo County, New Mexico. The mean plus or minus one standard deviation and the range (in parentheses) are shown for each sample.

Character	*M. californicus* (N = 50)	*M. leibii* (N = 34)
Total length	84.52 ± 4.69 (73.0–94.0)	89.06 ± 4.16 (80.0–99.0)
Tail length	39.00 ± 3.03 (32.0–45.0)	41.50 ± 2.71 (37.0–49.0)
Hindfoot length	6.82 ± 0.92 (5.0–8.5)	7.71 ± 0.62 (6.0–9.0)
Ear length	13.72 ± 1.03 (11.0–15.0)	14.70 ± 0.97 (12.0–16.0)
Forearm length	32.52 ± 1.07 (30.45–35.22)	33.49 ± 0.93 (31.28–35.77)
Tibia length	13.98 ± 0.83 (12.30–15.75)	13.88 ± 0.60 (13.11–15.34)
Condyle-premaxillary length	12.69 ± 0.27 (12.10–13.33)	13.33 ± 0.27 (12.73–13.88)
Condylocanine length	11.98 ± 0.26 (11.50–12.60)	12.60 ± 0.26 (11.99–13.07)
Maxillary toothrow length	4.99 ± 0.13 (4.64–5.25)	5.26 ± 0.13 (5.02–5.57)
Cranial breadth	6.27 ± 0.17 (5.95–6.65)	6.49 ± 0.13 (6.24–6.79)
Cranial depth	4.58 ± 0.17 (4.19–4.95)	4.42 ± 0.13 (4.13–4.80)
Interorbital breadth	3.09 ± 0.09 (2.90–3.28)	3.25 ± 0.14 (2.91–3.52)
Rostral breadth	4.81 ± 0.13 (4.51–5.10)	5.33 ± 0.13 (5.00–5.63)
Rostral length	5.33 ± 0.28 (4.32–6.00)	5.56 ± 0.26 (5.02–6.30)

Rohlf and associates). These last two analyses supported the discriminant analyses and therefore are not reported herein.

RESULTS AND DISCUSSION

An impressive array of investigators (Hall and Kelson, 1959; Cockrum, 1960; Barbour and Davis, 1969; Anderson, 1972; Armstrong, 1972; Findley et al., in manuscript) have used the same basic set of characters [first presented by Miller and Allen (1928)] to separate *Myotis californicus* and *M. leibii* (Table 1). In the Southwest, however, no single

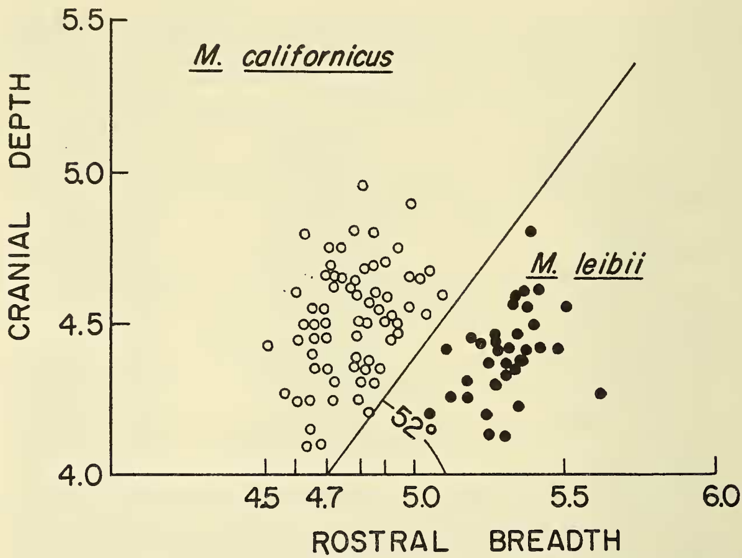

FIG. 1. Relationships of two cranial measurements in *Myotis californicus* and *M. leibii.* Measurements are in millimeters.

TABLE 3. Discriminant coefficients for original variables to be used in computing discriminant scores for unknowns. See text for details.

Variable	Coefficient
Total length	0.00508
Tail length	0.00019
Hindfoot length	–0.02895
Ear length	–0.01790
Forearm length	0.01046
Tibia length	0.02176
Condyle-premaxillary length	–0.18182
Condylocanine length	0.02349
Maxillary toothrow length	–0.06011
Cranial breadth	–0.00339
Cranial depth	0.30601
Interorbital breadth	0.14769
Rostral breadth	–0.43839
Rostral length	0.07154

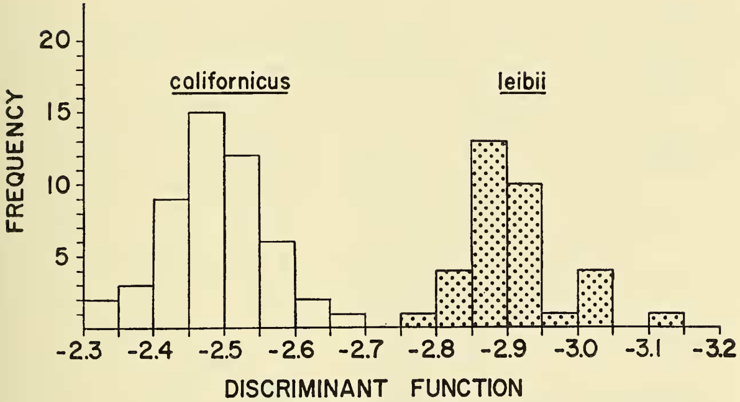

FIG. 2. Frequency distribution of Hidalgo County samples of *Myotis californicus* and *M. leibii* on the discriminant function computed by the two-group discriminant analysis.

qualitative character provides certain identification. Rather, all such characters must be considered simultaneously in a typically time-consuming operation. The quantitative character most often cited, that of third metacarpal length, was so variable within *californicus* that it was not further considered as an effective means to distinguish *californicus* from *leibii*. The basic statistics and amount of character overlap between the two species in Hidalgo County are shown in Table 2. The character showing the least amount of overlap in my analysis is rostral breadth as measured at the junction of M_1–M_2; 96% of *californicus* not exceeding 5.0 mm, and 92% of *leibii* equalling or exceeding 5.2 mm.

Most of the bivariate scattergrams were useless for separating the two species. The exceptions were rostral breadth plotted against other skull parameters; the most discriminating being rostral breadth against cranial depth (Figure 1). This useful combination is a reflection of *Myotis leibii* having a flattened skull, and *M. californicus* possessing a more globose skull. I have subsequently plotted rostral breadth against cranial depth for numerous specimens of both species from elsewhere in the southwestern U. S. and Mexico with equally good separation. Only rarely do specimens overlap the 52° line separating the clusters of *leibii* and *californicus*.

The results of the bivariate scattergram of Figure 1 were extended by performing a discriminant analysis to maximize the separation of the two species of bats. The results of this analysis are presented in Figure 2, and show a clear separation between the two groups. This analysis yielded the discriminant coefficients listed in Table 3 which can be used in determining identification of unknowns. The procedure, described in

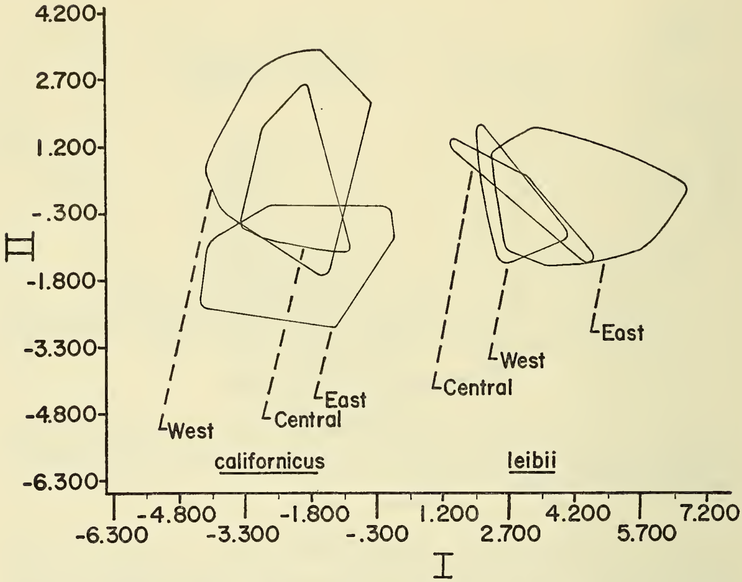

FIG. 3. Distribution of *Myotis californicus* and *M. leibii* on the first two canonical variates computed by the stepwise discriminant analysis. Each species is represented by three samples from western, central and eastern Hidalgo County. Lines enclose all bats within a sample.

Choate (1973) and elsewhere, is to multiply the value for each character by the discriminant coefficient, sum these values, and then plot the value on the discriminant function as shown in Figure 2. As Choate (1973) points out, the importance of extreme care in taking the measurements cannot be overstressed.

The multiple stepwise discriminant analysis using six groups (three *californicus* and three *leibii* samples) is of interest for at least two reasons. First, since the variables are entered in a stepwise fashion, the analysis enables the investigator to determine which variables possess the greatest discriminating power; and second, since the samples are subdivided it is possible to define a five-dimensional space within which the bats are dispersed. As seen in Table 4 the variable possessing the greatest discriminatory power among the 14 original variables is rostral breadth. Figure 3 is a plot of the six samples on the first two canonical variates and clearly shows that the two species do not overlap. The first two canonical variates account for 84% and 8% of the variance, respectively, and the first four variates account for 98.7% of the total variance.

These analyses demonstrate the distinct nature of the two taxa, and thus support the opinions of other investigators, and they enable the

TABLE 4. Rank order of variables as determined by the stepwise discriminant analysis. Those variables at the top of the column possess the greatest discriminatory power.

Rank	Variable
1	Rostral breadth
2	Hindfoot length
3	Cranial depth
4	Ear length
5	Maxillary toothrow length
6	Total length
7	Cranial breadth
8	Tibia length
9	Rostral length
10	Condyle-premaxillary length
11	Condylocanine length
12	Interorbital breadth
13	Forearm length
14	Tail length

rapid allocation of specimens of unknown identity. Proper identification, however, requires the presence of a clean, intact skull. It is disappointing that this study did not reveal any completely reliable character facilitating positive identification of these species in the field. Field identification still requires the utilization of traditional characters coupled with considerable experience. The most important feature is that *leibii* is usually darker in color than *californicus.* The exceptions are found in populations of dark-colored *californicus* occurring at higher elevations in the southwestern U. S. and Mexico. Furthermore, *californicus* usually appears to be distinctly smaller and more aggressive than *leibii.*

Having demonstrated that the two taxa are distinctive the intriguing question is, how are they partitioning the environment in areas of sympatry? Black (1972), based on his study of bat food habits, suggests that one member of the pair might be a "beetle strategist" while the other may prey more heavily on moths. Husar (1973) has recently described such a situation in *Myotis evotis* and *M. auriculus*, two very similar bats with rather narrow regions of overlap in the southwest. Geluso (1972) has shown that *californicus* and *leibii* are physiologically different in urine concentrating abilities and in kidney morphology. These investigations suggest that *californicus* and *leibii* are at least as different ecologically and physiologically as they are morphologically and they may be minimizing competition through differences in diet, roosting or foraging sites, or foraging times. Such partitioning should be demonstrable through observable differences in dietary, behavioral, or physiological parameters.

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